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(6) CALIBRATION OF A LARGE ACOUSTIC ARRAY AT LAKE SAN VICENTE, LAKESIDE, CALIFORNIA.

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CALIBRATION OF A LARGE ACOUSTIC ARRAY AT LAKE SAN VICENTE, LAKESIDE, CALIFORNIA

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The purpose of this calibration was to examine the farfield beam pattern of an acoustic array which weighed 1,836 lbs in air. (Figure 1.) Calculations showed that a source to receiver distance of at least 77 m (≈225 ft) was required to provide the farfield output of the measured array. This range requirement and weight burden demanded new methods compared to the established calibration methods used by MPL to date.

The work was conducted from the MPL maintained barge in the San Vicente reservoir. The barge is anchored by a four point moor in ≈160 ft depth (depending on season). The site is approximately 680 ft from the main spillway of the San Vicente Dam. Although other literature[1/] gives particulars of the barge and lake, very little information was available which was applicable to calibration work on such a large physical scale. It was, therefore, decided that a bathymetric survey of the area adjacent to the barge would be conducted. For this purpose a Raytheon portable recording fathometer was used in conjunction with two transits set on known survey marks on the dam. A small boat crew, radio linked with the two surveyors, profiled the bottom on

radial lines originating from the barge. The depth points were marked simultaneously with angular measurements taken from the two transits. This gave an accuracy of ≈ 3 m which was sufficient for our interest in discovering any unmarked topographical or man-made targets which would be in the beam path. A further examination of the lake was made with a thermistor temperature probe to a depth of 40 m. These measurements were taken at points accurate to ≈ 3 m and at depths accurate and repeatable to ± 2 cm. This survey was repeated during the course of the calibration work which spanned a period of two months, July and August 1975. The depth survey showed no obstructions and the contours of the bottom were in agreement with known topography. The temperature profile of the lake showed a definite thermocline to ≈ 60 ft. (Figure 2.) This thermocline did not appear to cause acoustic problems with the calibration.

An operating depth of 60 ft was chosen, which would provide sufficient depth to prevent any surface reflection from interfering with the calibration. To reach this depth with an 1800 lb load required development of much stronger equipment than was available. Severe cost limitations also posed problems with the entire project. Existing equipment on the barge was used to the greatest possible extent to keep the cost down. Minimal machine work kept the labor costs to a minimum. Despite these limitations it was hoped that the mechanical system would have a cumulative accuracy of 1/2° in the radial plane. It was further required that the array could be rotated axially to obtain

a three dimensional view of the beam. Calibration requirements assumed that the target hydrophone and the array (ie. barge) were stable in the radial plane. Neither the barge nor the target remained fixed so a method was necessary to compensate for this motion. Other limits on design were the physical dimensions of the barge and its equipment.

The barge is 24' x 50' with two separate hulls. A well is formed between the two hulls, which is spanned by three thwartship braces, a minimum of 44 3/4 in. apart. Unfortunately, as the array's size is much larger than this dimension on any axis, it could not be raised or lowered through the well. The barge has two chain hoists, with a maximum vertical travel of 17 ft, which could be used in the deployment operations.

It was necessary to develop methods to deliver the array to the dam site, transport it $\approx 1/4$ mile to the barge, support it under the barge at a depth of 60 ft, position it with great accuracy, raise and lower it simply and retrieve the system without the use of scuba divers or very heavy equipment. The safety of the array and the workers were also part of the overall plan.

Transport to the lake site was arranged through the Mechanical Development Shop of MPL. They have available a 5 ton, 6 x 6 WD, truck with a two ton articulated crane. This allowed the array to be loaded at the shop and placed directly in the water, completely assembled. An air bag of ballistic nylon was custom built to the inside dimensions of the array. When inflated

the bag provided bouyancy such that the array would float. A small barge of $\approx$ 15' x 8' was then rafted up to the array to provide a margin of safety and to allow the attachment of a small motor boat. The small boat then towed the barge/array to the main barge.

To support the array under the barge a simple method was used. Three 20 ft sections of Std. 2 in. steel pipe (galvanized) were cut to 10 ft lengths, giving 6 each 10 ft lengths of pipe.[2/] These were welded to stock 150 psi, four bolt, forged steel pipe flanges. Flanges were also welded to the array in a pattern allowing attachment at various points. All of these points were on the center of gravity plane so balance was excellent and placed no measureable bending moment on the pipe. A further refinement for balance was that two of the attachment points were removable, thereby eliminating any axial torque about the center line of the array.

With the array positioned near the barge, at right angles to the center well, one 10 ft pipe was bolted to a matching flange on the array. This was done at the surface and the pipe was led under the thwart ship brace and connected to the electric hoist. The array was then cast loose from the small barge and the air bag was deflated. The array then sank to a depth of $\approx$5 ft swinging under the barge as the strain was taken by the crane. This took place at a controllable rate by valving the air release and with the use of tag lines. The array was then raised as high as possible in the well and the air bag was removed.

The array could then be lowered 10 ft and set into a pair of jaws which clamped shut around the pipe, supporting the weight via the flange.

The lifting flange was then unbolted and attached to another pipe section, raised, and then attached to the flange in the jaws. (Figure 3.) The weight was then taken by the crane and the jaws were opened. The pipe string was then lowered. Once clear of the flange joint the jaws were again closed, guiding the pipe through the well. This process was repeated four more times to reach the desired depth. After the last pipe was set in the jaws the lifting flange was removed and a gimbaled support was bolted to the flange. This gimbal contained turning gears, a motion compensation system, and a sine-cosine potentiometer to provide directional information.

The gimbal system, though of very rugged steel construction, was light enough to be handled by two men. The main bearing was load tested to 3000 lbs static load. The actual turning was done via a hand crank and gear train terminating in a large worm/ring gear drive. This ring gear also drove another gear train to rotate the shaft of the sine-cosine pot, which gave the array's rotational position to an X-Y plotter. The unique part of the gimbal is the motion compensator system.[3/] This was important because the barge will drift within its mooring in a 7° arc at speeds faster than the sample electronics of the target hydrophone will read out on the X-Y plotter. The system employs a rifle telescopic sight mounted on a geared shaft. Two hand controls allow a coarse and fine adjust of the sight. These controls were also geared to the body of the sine-cosine pot. By this mechanism the operator can sight on a target and adjust the sight to compensate the barge's movement relative to the apparent

radial position of the array on the plotter. (Figure 4.) This system allowed repeatable runs to be made under varying drift conditions.

The receiver hydrophone was positioned 408 ft from the barge by means of a taut moored buoy.[4] The electronics cable for the hydrophone was secured to floats and led to the barge. The mooring line was of braided heaving line which, after a period of break-in, stretched little. This was attached to a 100 lb weight and lowered to the bottom. A clip was then tied to the line and a buoy was forced down approximately 2 ft. The buoy provided 65 lbs lift when clipped to the line. This lift was sufficient to make the moor taut. A large rectangular frame of (free flooding) PVC was assembled from stock fittings and 1 in. pipe. To this frame the receiver hydrophone and its electronics were attached. The frame was then clipped on the mooring line and lowered via a tag line to the desired depth. An additional line was led to the surface $\approx$ 40 ft towards the barge and tied to the electronics cable. This prevented the hydrophone from turning about the mooring line, and kept the phone in the proper vertical orientation. (Figure 5.)

Axial rotation of the array was accomplished by raising the pipe string up and disassembling it in the reverse order that it was lowered. When the last pipe section was reached, the array was lifted as high as possible to the surface with a manual chain fall. The array was then turned radially 90° to the well so that the next flange on the array was pointed towards the dam. To this flange another pipe was attached, the other end of which was secured to the electric

crane. The manual chain fall was then lowered and the strain was transferred to the electric crane. This allowed the array to rotate 45° axially. The first pipe and the fittings on the array were then removed to gain proper balance. The array was then lowered on the pipe string to the required depth. The rotation process was again repeated so that the array was rotated a total of 90° axially from the original orientation. (Figure 6.)

This rotation method proved to be safe and simple enough that it was decided to lift the array out of the water and partially disassemble it upon completion of the calibration. The process of rotation was similar except that the second pipe was led under the thwartship brace and attached to the electric crane outboard of the barge. This swung the array out from under the barge when the load was transferred. The array was then raised as high as possible and pulled in, onto the deck (approximately 1 in. clearance). Once disassembled, the main frame of the array was loaded on the deck of the small barge. The small barge was then towed to the beach and the array was removed by the crane truck.

Safety was considered very important since the weight of the array posed very real hazards. A safety chain was attached to the array and to the barge at all times. All mechanical operations were done at as shallow a depth as possible. This depth rarely exceeded 5 ft and usually required that a worker only reach into the water. The pipe string operation required no wet work and no heavy lifting.

A total of 60 calibration runs were made on the array. The data conformed well with previous theoretical calculations. This allowed confidence in the method used to correct the barge's motion. The system proved to be easy to operate, safe and durable.

This work was sponsored by ARPA monitored by ONR on Contracts N00014-69-A-0200-6041 and N00014-75-C-1023. Mr. L. M. Occhiello, Project Engineer, provided much direction and many ideas to make this project successful.

APPENDIX I

Lee Tomooka

A. Pipe Stress

Because the pipe is hung from the gimbal there is only tensile stress in the pipe.

$$\delta = {}^{D_m}/_A$$

$$D_m = 1200 \text{ lbs (in water)}$$

$$A = \pi/_4 \left(OD^2 - ID^2\right) = 1.07 \text{ in.}^2$$

$$\delta \cong 1100 \text{ psi}$$

for steel pipe δ (yield) $\cong$ 60,000 psi giving a safety factor 5 gives δ (allowable) = 12,000 psi

therefore jaw and hoist working loads are the limiting factors in this consideration.

B. Array Deflection

Typically worse case barge motion is about 30 ft min^{-1}, or 0.5 ft sec.$^{-1}$.

Assuming steady state at this speed, the drag is;

$$D = {}^1/2\, C_D\, \rho A V^2$$

Let $C_D = 1$

$\rho = 62.4$ lb ft^{-3} (fresh water)

A = 51" x 51" = 18.06 ft^2 (array end view)

$$D = 8.75 \text{ lbs}$$

The pipe deflection angle is;

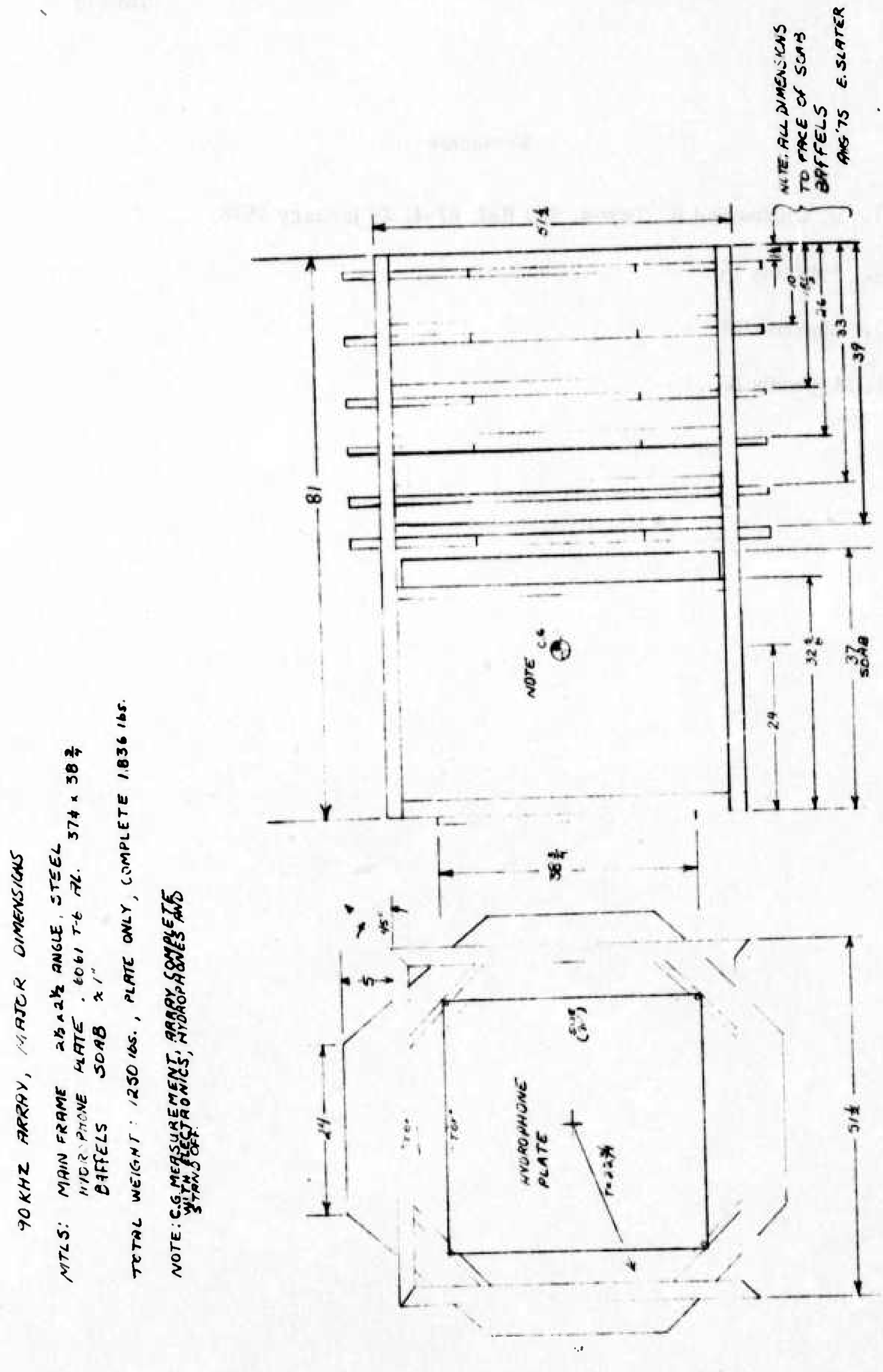
$$\text{Arctan}\left({}^{D}/D_m\right) = \text{Arctan}\left(\frac{8.75}{1200}\right) = 0.42°$$

Since the beam pattern has a null about 1° from center, drift rates or subsurface currents greater than 0.5 ft sec.$^{-1}$ could cause the array to miss the receiver hydrophone either above or below.

Footnotes

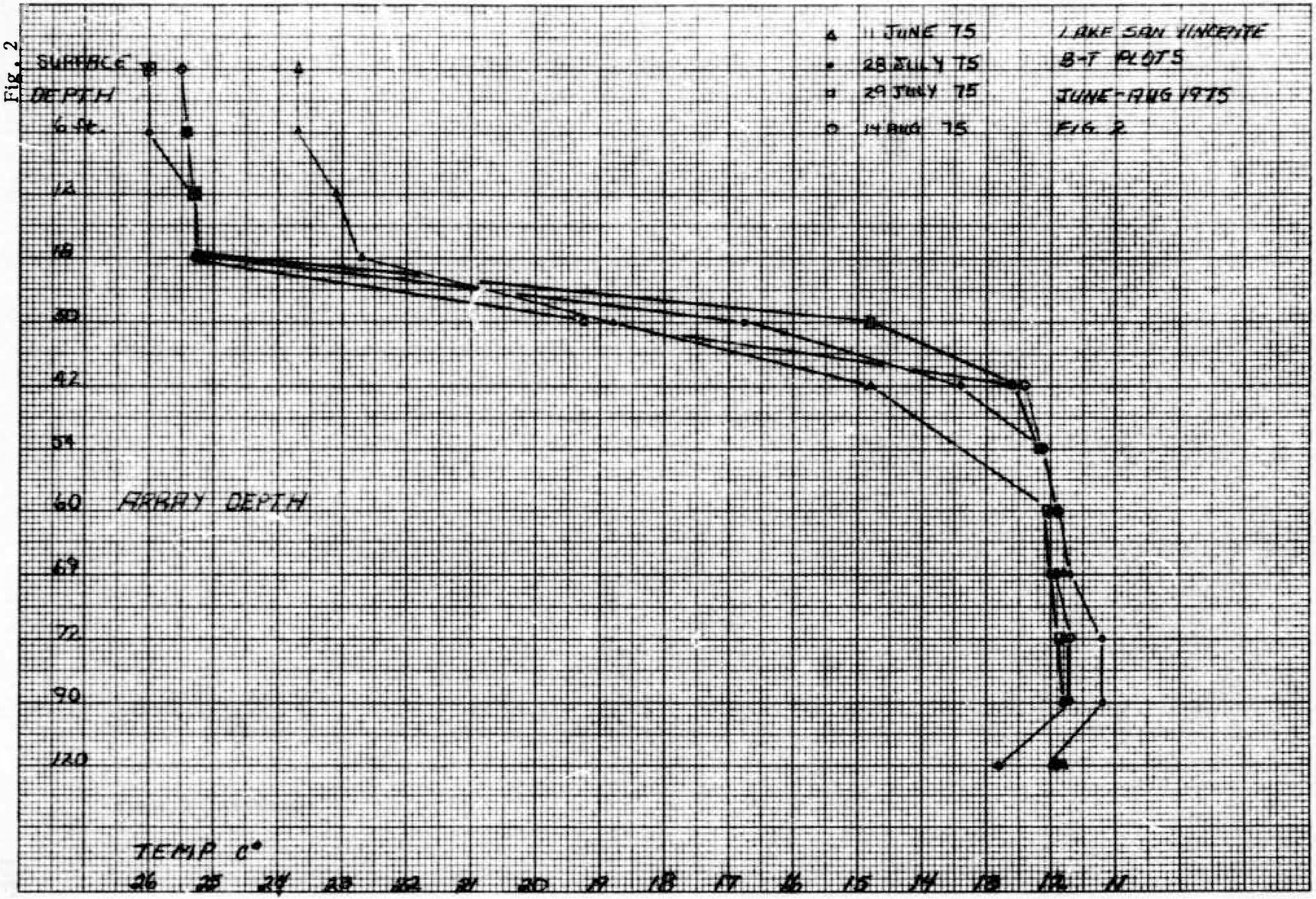
1. D. Gibson and R. Lewis, SIO Ref. 67-4, 20 January 1974.
2. Appendix IA
3. Appendix IB
4. Appendix IC

Fig. 1



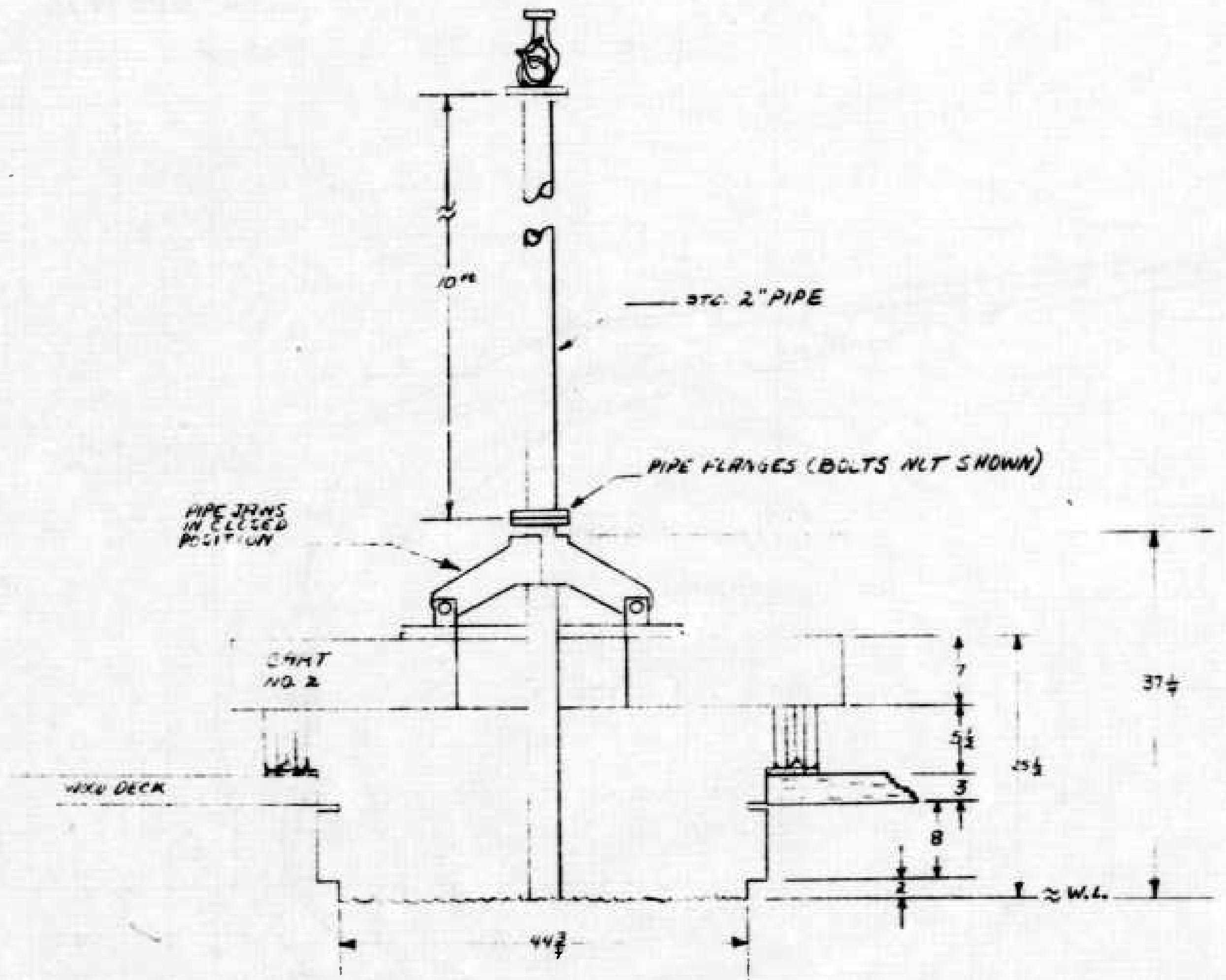
90 KHZ ARRAY, MAJOR DIMENSIONS
MTLS: MAIN FRAME 2½ x 2½ ANGLE, STEEL
HYDROPHONE PLATE, 6061 T-6 AL. 37¼ x 38¾
BAFFELS SOAB x 1"
TOTAL WEIGHT: 1250 lbs., PLATE ONLY, COMPLETE 1,836 lbs.
NOTE: C.G MEASUREMENT, ARRAY COMPLETE WITH ELECTRONICS, HYDROPHONES AND STAND OFF.
24
5
45°
HYDROPHONE PLATE
51½
38¾
81
NOTE C.G
51¼
24
32⅝
37 SOAB
10
39
26
33
NOTE. ALL DIMENSIONS TO FACE OF SOAB BAFFELS
AUG '75 E. SLATER

Fig. 2



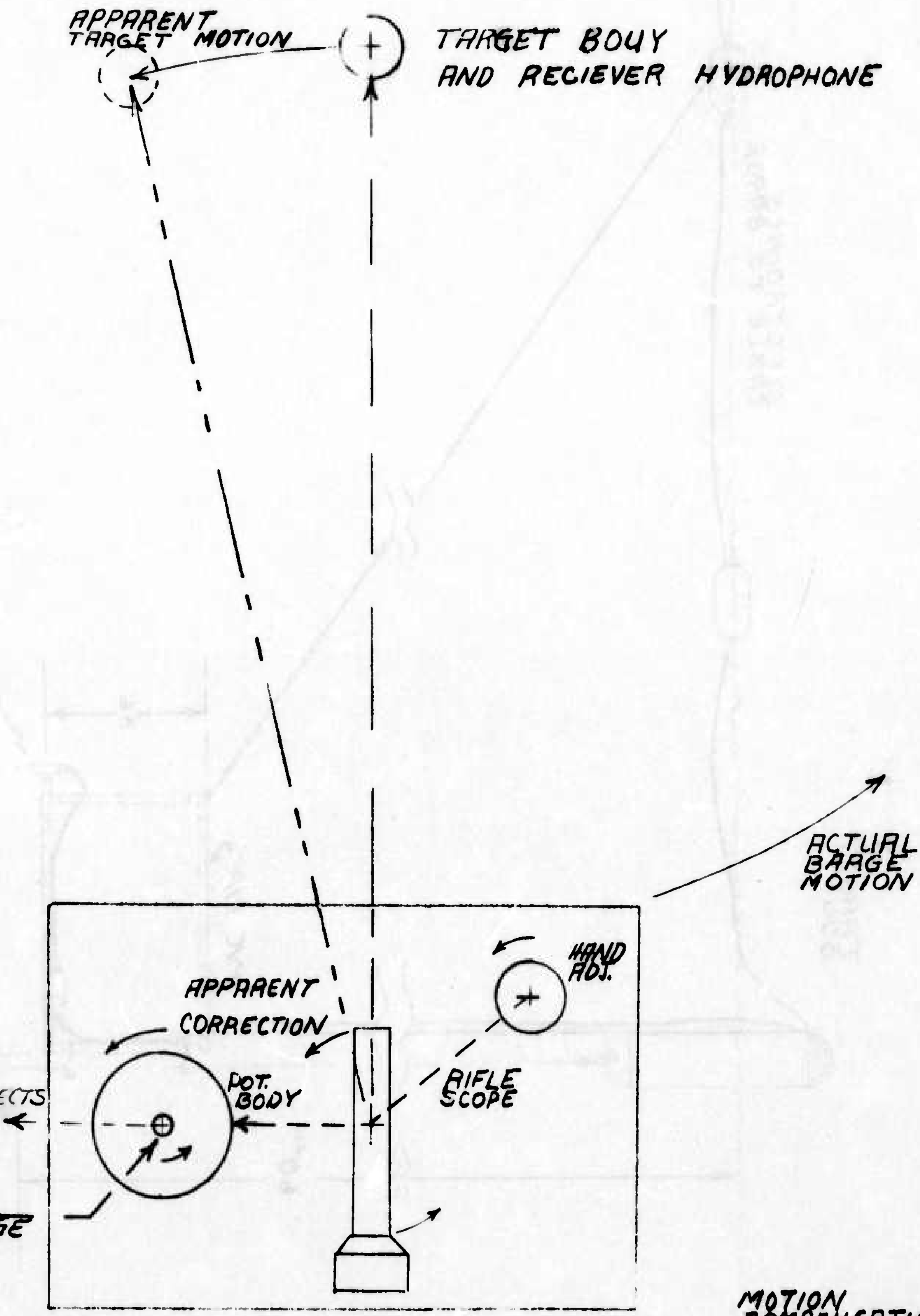
LAKE SAN VINCENTE
B-T PLOTS
JUNE-AUG 1975
FIG. 2
11 JUNE 75
28 JULY 75
29 JULY 75
14 AUG 75
SURFACE
DEPTH
6 ft.
12
18
30
42
54
60
67
72
90
120
ARRAY DEPTH
TEMP C°
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11

Fig.3



GENERAL CART DIMENSIONS
AS VIEWED FROM DAM END
OF BARGE

AUG 1975   E. SLATER



MOTION
COMPENSATION
BLOCK DIAGRAM
FIG. 4

E SLATER
AUG 1975

Fig. 5

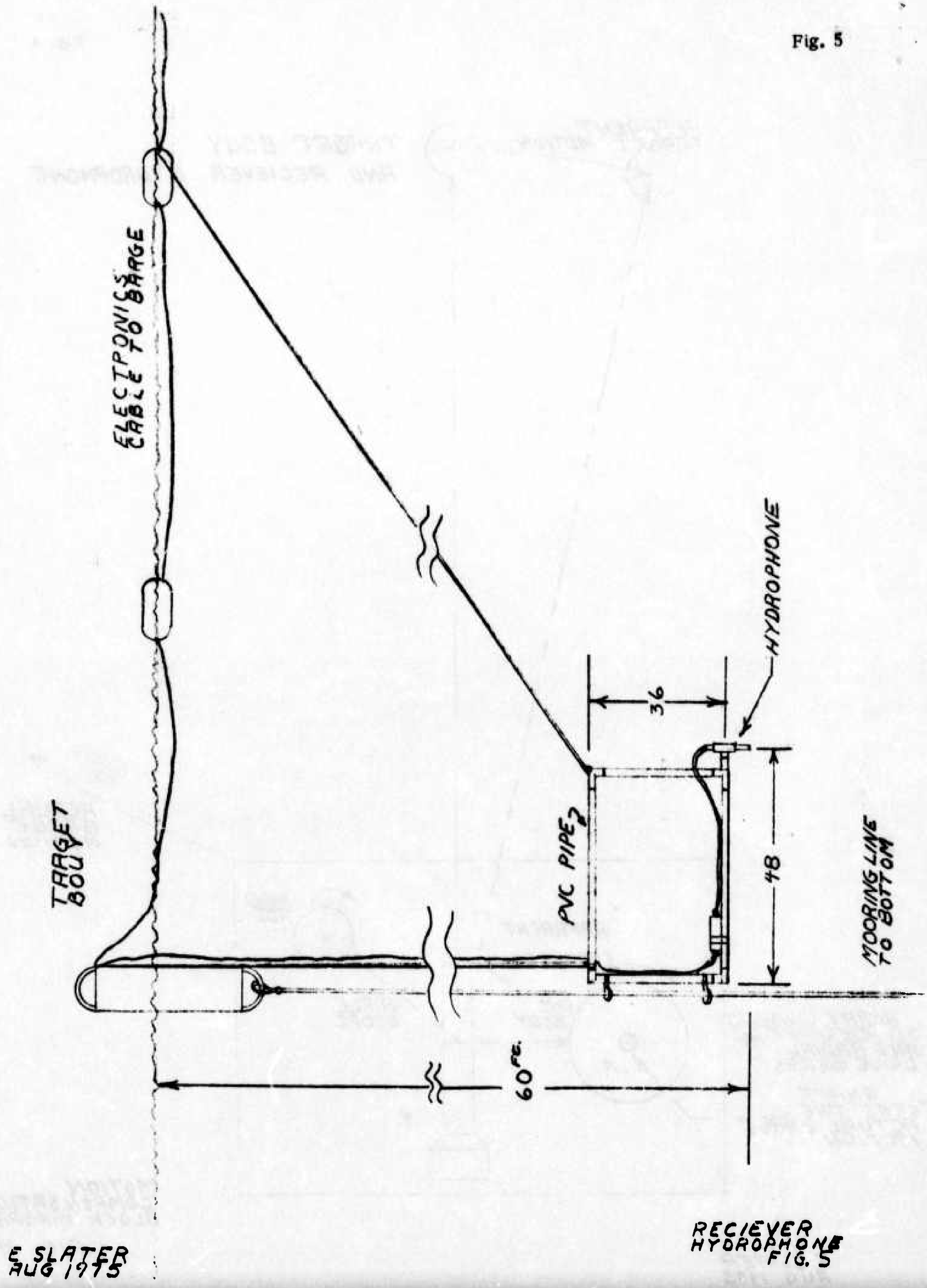
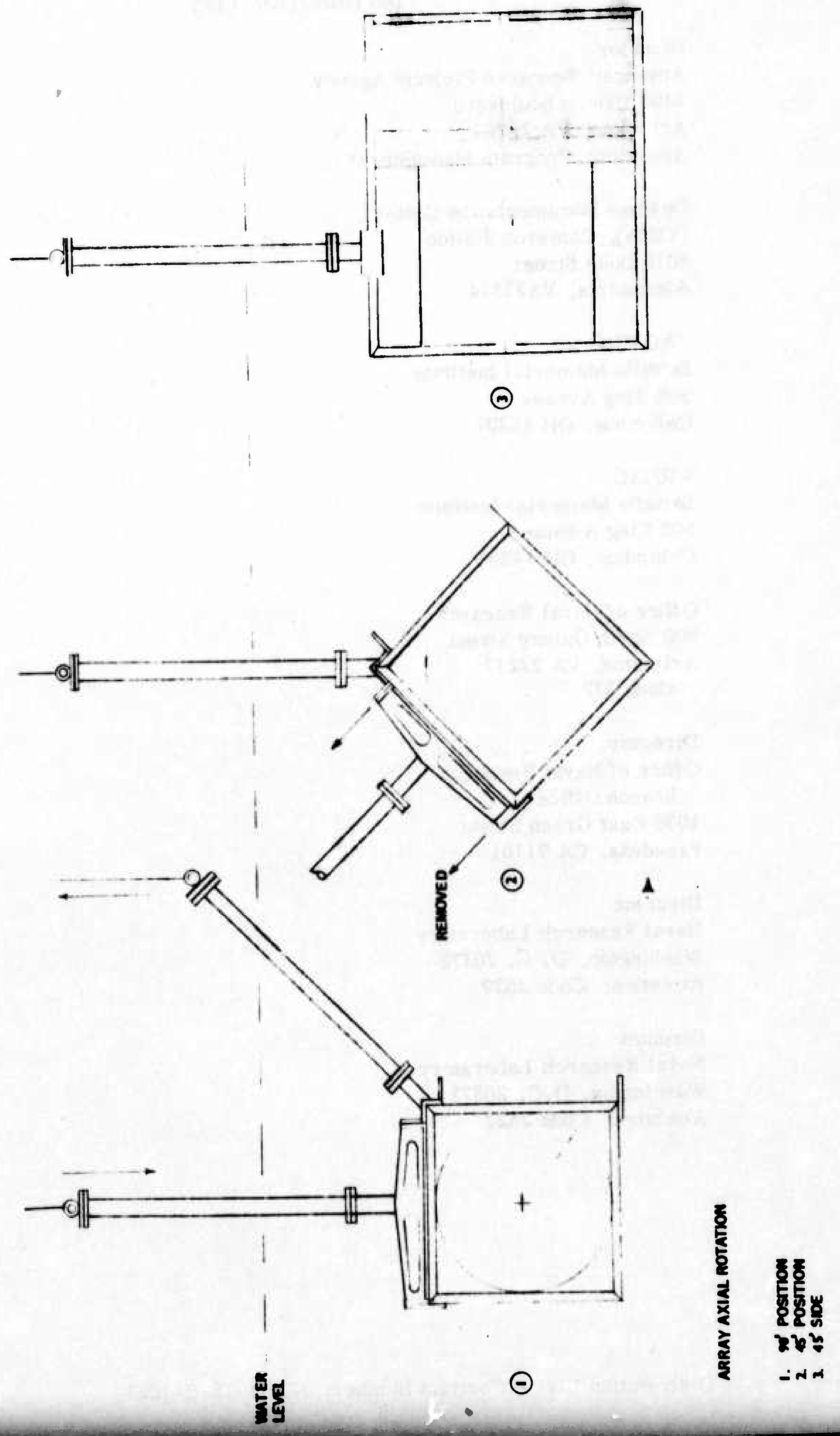

ELECTPONICS CABLE TO BARGE
TARGET BOUY
PVC PIPE
HYDROPHONE
36
48
MOORING LINE TO BOTTOM
60 Ft.
E SLATER AUG 1975
RECIEVER HYDROPHONE FIG. 5

Fig. 6



WATER LEVEL
REMOVED
ARRAY AXIAL ROTATION
1. 90° POSITION
2. 45° POSITION
3. 45° SIDE

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